BRIEF REPORT

Near-Infrared Laser Spectroscopy as a Screening Tool for Detecting Hematoma in Patients with Head Trauma

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Abbreviations:
CT = computed tomography
GCS = Glasgow Coma Scale
NIR = near infrared
NIRS = near-infrared spectroscopy
OD = optical density

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Abstract

Introduction: Among imaging techniques, computed tomography (CT) is a reliable method for detecting intracranial hematomas in patients with head trauma, but it is not generally available in special circumstances like prehospital situations and harsh conditions such as those following an earthquake.

Objective: The objective of this study is to determine if near-infrared spectroscopy (NIRS) is useful for performing CT scans on patients with closed head trauma that present to medical centers that do not have the ability to perform a CT scan or in prehospital or harsh situations. Near-infrared spectroscopy and CT scan were compared according to sensitivity and specificity.

Methods: This was an observational, prospective study. One hundred forty-eight patients admitted to Rasool Akram General Hospital in Tehran, Iran with head injuries during a one-month period were studied using NIRS and CT. The observational, prospective study was conducted and sensitivity, specificity, positive and negative predictive values of NIRS were calculated. Chi-square and Kappa analysis was performed, and a *p*-value <0.05 was considered significant.

Results: According to the CT scan findings, 54 (36.5%) of the patients developed intracranial hematoma. The NIRS examination showed that 69 patients (46.6%) might have intracranial hematoma. The number of true negatives was 73 and the number of false negatives was six patients. The sensitivity and specificity of NIRS examination was 88.9% and 77.7%, respectively.

Conclusions: This study speculates that NIRS may be a useful screening tool to detect intracranial hematoma. This capability could be useful in special situations like in a deprived area, medical centers without CT scan capabilities, prehospital situations, and in harsh conditions like those after an earthquake or other disasters that causes increased numbers of victims with closed head trauma.

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Introduction

Closed head trauma is one of the most prevalent hospital emergencies. Patients with closed head trauma may develop intracranial hemorrhage, which is an important cause of secondary brain injury. Early identification and treatment of intracranial hemorrhage improves neurological outcomes.[1]

Among imaging techniques, computed tomography (CT) is a reliable method for detecting intracranial hematomas. However, there are some limitations for using CT. These situations include disasters following earthquakes or floods, which increase the load of patients with head trauma. This presents a major challenge in areas in which CT scan facilities do not exist, when the distance between primary medical centers to a trauma center equipped with CT scan capabilities is far, and in ambulances. In addition, CT scans require that patients, many of whom are critically ill, be taken out of the emergency department to be scanned, in addition the yield is relatively low when serial scans (for detecting a delayed hematoma) are obtained in all patients. Clinical monitoring techniques for the accurate selection of patients requiring follow-up CTs would improve the yield.[2–4] Patients with multiple traumatic injuries, who are hemodynamically unstable, and who should undergo emergent surgery, a CT scan should not be performed, as it is time-consuming. Also, in the emergency department, triage will become more accurate if physicians can employ available, non-invasive, and less expensive techniques.

Since the first publication by Jobsis in 1977,[5] near-infrared spectroscopy (NRIS) has been used to investigate cerebral hemodynamics in a variety of studies.[6–8] Near-infrared spectroscopy is capable of measuring the amount of oxygen in hemoglobin.[9] Simple and non-invasive, NIRS has been used to monitor cerebral oxygenation and blood flow in children and adults in diverse conditions.[10] It has been used in severely asphyxiated neonates,[11,12] during circulatory arrest during cardiac surgery,[13–15] and in adults with head injuries.[16,17] Absorption of near-infrared (NIR) light in the brain mainly is caused by hemoglobin. A superficial intracranial hematoma with a higher concentration of hemoglobin causes a higher absorption in NIRS. The existence of a hemorrhage can be demonstrated by the difference of optical density, comparing identical measuring points at both hemispheres of the brain: absorption of NIR light is greater on the side of the hemorrhage, causing less reflection in NIRS.[18]

Delayed intracranial hematoma also is a treatable cause of secondary brain injury in patients with closed head trauma. Early identification and treatment of these mass lesions, which appear or enlarge after the initial CT scan, may improve neurological outcome. Serial examinations using NIRS to detect the development of delayed hematoma can be performed.[19]

Methods

In order to find inexpensive, easy to perform, portable, and non-time-consuming tools used to screen or triage patients with closed head trauma and intracranial hemorrhage in harsh situations such as in earthquake-affected areas, non-equipped centers, or ambulances, NIRS was studied and compared to CT scan. Sensitivity, specificity, and positive and negative predictive values of NIRS were calculated. If the sensitivity and specificity of NIRS would be acceptable, NIRS could be used for detecting intracranial hematoma in such special situations.

Participants

One-hundred forty-eight patients with head injuries and who required brain CTs and who were admitted to Rasool Akram General Hospital during a one-month period in 2007, were studied with both NIRS and CT.

Study Design

An observational, prospective study was conducted. All patients first were evaluated using a CT scan and then with NIRS. A CT was repeated if indicated for the purpose of diagnosing delayed intracranial hematomas. (Six patients had indication for repeating CTs). The radiologist who reported the CT scan results and the doctor who used the NIRS device were blinded from each other's interpretations.

Clinical Assessments

All of the participants were examined using the NIRS (CrainScan, BYTEC, Germany). The difference in the optical density (OD) between the two sides was determined.[20]

The difference in the OD was calculated for each of the paired regions. According to the instrument instruction, the difference in OD >0.45 was considered clinically significant.

Statistical Methods

Statistical comparisons were performed using commercially available statistics software (SPSS version 15 for windows, SPSS Inc. Chicago, IL). Values are expressed as mean ±standard deviation. Chi-square and Kappa analysis was performed. The CT brain scan findings were used as the standard reference to compare the significance of the NIRS system findings. Sensitivity, specificity, positive and negative predictive values were calculated. A p-value <0.05 was considered statistically significant.

The researchers were committed to the declaration of Helsinki Treaty throughout the research, and this study was approved by the Iran University of Medical Science (IUMS) Ethical Board.

Results

A total of 148 patients admitted to the hospital due to closed head trauma were studied. The age of the patients ranged from 11–78 years. The mean value for the ages was 36.8 ±16.69. Fifty-four patients (36.5%) were female and 94 (63.5%) were male (male/female ratio = 1.7). The mechanisms of trauma are listed in Table 1. The mechanisms of trauma were not statistically different between males and females (p >0.05).

Based on the CT scan findings, 54 patients (36.5%) developed an intracranial hematoma. Because the CT has been validated for detecting intracranial hematoma, the prevalence of intracranial hematoma in these patients with closed head trauma was 36.5%. The NIRS examination showed that 69 patients (46.6%) might have an intracranial hematoma. Out of 54 CT scan-detected cases of hematoma, 48 were detected by the NIRS system. Thus, the sensitivity of the NIRS was 88.9%. In the group of patients that did not have intracranial hematoma based on CT scan, 21 (22/3%) were detected to falsely have one by the NIRS system. Therefore, the specificity of the NIRS was 77.7%. Positive and negative predictive values, which could be altered by changing in prevalence, were 69.6% and 92.4% respectively. Kappa analysis demonstrated that the agreement between CT and NIRS was 62.8% (Kappa = 0.628), and it was a statistically significant association (p <0.01).

A logistic regression was performed to evaluate effects of gender, age, mechanisms of trauma, and Glasgow Coma Scale (GCS) scores on NIRS findings. The analysis indicated that none of these variables predicted the presence of a hematoma. Thus, the sensitivity and specificity of a NIRS examination is independent from gender, age, GCS score, and mechanisms of trauma.

In the patients studied, three had hematoma in the posterior fossa and nine had a hematoma in the subglial area. Because NIRS could not detect the hematoma in posterior fossa and the result from the subglial area was a false positive, those cases were omitted, and all above parameters were calculated again. The results are listed in Table 2.

Discussion

The results of this study show that in comparison with CT scan, NIRS sensitivity and specificity are 88.9% and 77.7%

Mechanism	Male n (%)	Female n (%)	Overall n (%)
Accident	66 (70.2)	39 (72.2)	105 (70.9)
Falling Down	15 (16)	10 (18.5)	25 (16.9)
Fight	11 (11.7)	4 (7.4)	15 (10.1)
Exercise	2 (2.2)	1 (1.9)	3 (2)

Table 1—Mechanisms of trauma in patients who were admitted in Rasool Akram General Hospital over a one-month period

	Sensitivity %	Specificity %	PPV %	NPV %
Without posterior fossa hematoma	94.1	77.7	69.6	96.1
Without subglial hematoma	88.9	85.9	80.0	92.4
Without either	94.1	85.9	80.0	96.1

Table 2—The sensitivity, specificity, positive and negative predictive values (PPV, NPV) when posterior fossa and subglial hematomas excluded

respectively, and when posterior fossa and subglial hematomas were excluded, the sensitivity and specificity increased significantly. This result is important because it may help to find a more reliable device to use as a screening tool of patients with closed head trauma.

Although the results are statistically significant, the short study period, limited number of patients, and the inclusion all patients with CT scan indication instead of a random selection of patients are limitation of this study. These could not be prevented due to budget and time restraints. Furthermore, NIRS may have some limitations. Optical differences between right and left were not significant for deeply located lesions, bilateral abnormalities, and small hematomas. In addition, NIRS is not a reliable tool for detecting of hematoma in the posterior fossa and subglial region.

On the one hand, NIRS could be considered a portable, simple, non-invasive screening tool to identify large, superficially placed, unilateral, intracranial hematoma.[20] Early identification of delayed hematomas before any neurological consequences occur is another benefit of NIRS. One study showed that even if the serial CT scans were performed on every patient within the first 24 hours post-injury, no more information would be obtained than with the serial NIRS examinations.[2] Therefore, early diagnosis using NIRS may allow early treatment and reduce secondary injury caused by delayed hematomas.[1,2,19]

A previous study demonstrated that NIRS performed in the emergency department reliably identified the presence of a traumatic, intracranial hematoma in each of 40 patients in whom a CT scan also revealed the presence of a hematoma.[17] In another study, the sensitivity and specificity of NIR measurement was 98% and 100%, respectively.[21] Higher sensitivity and specificity of both these studies than the current study may be due to better quality instruments. Attempts should continue in order to reach higher quality in NIRS instruments.

Conclusions

Due to its positive characteristics such as safety, easy performance, portability, non-time-consuming usage, inexpensive preparation and nearly acceptable sensitivity and specificity, NIRS could be used as a screening tool for performing CT scans in patients with closed head trauma. This approach is most useful in harsh situations after earthquakes and floods, when the distance between primary medical centers to a trauma center equipped with CT scanning equipment is far and in ambulances.

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References

1. Hennes HJ, Lott C, Windirsch M, Hanley DF, Boor S, Brambrink A, Dick W: Noninvasive detection of intracerebral hemorrhage using near-infrared spectroscopy (NIRS). *Proc SPIE* 1997;3194:42–54.
2. Gopinath SP, Robertson CS, Contant CF, Narayan RK, Grossman RG, Chance R: Early detection of delayed traumatic intracranial hematomas using near-infrared spectroscopy. *J Neurosurg* 1995;83:438–444.
3. Bein B, Meybohm P, Cavus E, Tonner PH, Steinfath M, Scholz J, Deorges V: A comparison of transcranial Doppler with near infrared spectroscopy and indocyanine green during hemorrhagic shock: A prospective experimental study. *Crit Care* 2006;10(1):R18.
4. Baumgartner RW, Mattle HP, Aaslid R: Transcranial color-coded duplex sonography, magnetic resonance angiography, and computed tomography angiography: Methods applications, advantages, and limitation. *J Clin Ultrasound* 1995;23:89–111.
5. Jobsis FF: Non-invasive infrared monitoring of cerebral and myocardial oxygen sufficiency and circulatory parameters. *Science* 1977;198:1264–1267.
6. Brazy JE, Lewis DV: Changes in cerebral blood volume and cytochrome aa3 during hypertensive peaks in preterm infants. Pediatrics 1986;108:983–987.
7. Ferrari M, De Marchis C, Giannini I, DiNicola A, Agostino R, Nodari S, Bucci G: Cerebral blood volume and haemoglobin oxygen saturation monitoring in neonatal brain by near infrared spectroscopy. *Adv Exp Med Biol* 1986;200:203–211.
8. Francis SV, Ravindran G, Visvanathan K, Ganapathy K: Screening for unilateral intracranial abnormalities using near infrared spectroscopy: A preliminary report. *J Clin Neurosci* 2005;12(3):291–295.
9. McCornick PW, Goetting MG, Dujovny M, Ausman JL: Noninvasive cerebral optical spectroscopy for monitoring cerebral oxygen delivery and hemodynamics. *Crit Care Med* 1991;19:89–97.
10. Owen-Reece H, Smith M, Elwell CE, Goldstone JC: Near infrared spectroscopy. *Br J Anaesth* 1999;82:418–426.
11. Wyatt JS: Near-infrared spectroscopy in asphyxial brain injury. *Clin Perinatol* 1993;20:369–378.
12. Van Bel F, Dorrepaal CA, Benders MJ, Zeeuwe PE, Van de Bor M, Berger HM: Changes in cerebral hemodydynamics and oxygenation in the first 24 hours after birth asphyxia. *Pediatrics* 1993;92:365–372.
13. Ausman J, McCornick PW, Stewart M, Lewis G, Dujovny M, Balakrishnan G, Malik GM, Ghaly RF: Cerebral oxygen metabolism during hypothermic circulatory arrest in humans. *J Neurosurg* 1993;61:810–875.

14. Daubeney PE, Pilkington SN, Janke E, Charlton GA, Smith DC, Webber SA: Cerebral oxygenation measured by near infrared spectroscopy. *Ann Thorac Surg* 1996;61:930–934.
15. Kurth CD, Steven JM, Nicolson SC: Cerebral oxygenation during pediatric cardiac surgery using deep hypothermic circulatory arrest. *Anesthesiology* 1995;82:74–82.
16. Kirkpatrick PJ, Smielewski P, Czosnyka M, Menon DK, Pickard JD: Near-infrared spectroscopy use in patients with head injury. *J Neurosurg* 1995;83:963–970.
17. Gopinath SP, Robertson CS, Grossman RG, Chance B: Near-infrared spectroscopic localization of intracranial hematomas. *J Neurosurg* 1993;79(1):43–47.
18. Goldberg S, Lott C, Ostermeyer M, Hennes HJ: Near-infrared spectroscopy (NIRS) as a diagnostic tool in patients with suspected stroke or traumatic brain injury. *Proceedings of SPIE* 2001;4432:310–311.
19. Robertson CS, Gopinath SP, Chance B: Use of near-infrared spectroscopy to identify traumatic intracranial hematomas. *J Biomedical Optics* 1997;02(01):31–41
20. Francis SV, Ravindran G, Visvanathan K, Ganapathy K: Screening for unilateral intracranial abnormalities using near infrared spectroscopy. A preliminary report. *J Clin Neuro* 2005;12(3):291–295
21. Litscher G, Schikora D: Near-infrared spectroscopy for objectifying cerebral effects of needle and laserneedle acupuncture. *The Internet Journal of Neuromonitoring* 2003;3(1).